# Verification of a New Method in Determining the Viscosity of Fluids Under High Temperature and Pressure

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## Background

At convergent plate boundaries, an oceanic plate may subduct below another plate. Above the subducted plate, volcanoes are found. Hydrous minerals are carried to depths of 100 km and break down to release their stored water into overlying rock. As this water migrates toward the surface, it interacts with overlying mantle wedge and causes melting. Magma rises to the surface and can be seen as volcanic arcs on the surface.

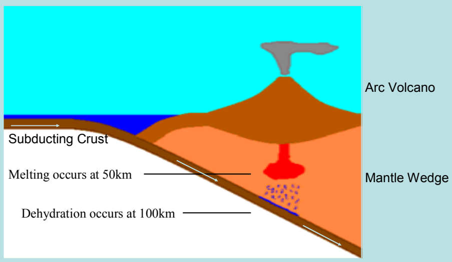


**Figure 1:** *Simplified view of a subduction zone with dehydration occurring at 100 km.*

Knowledge of the viscosity of the freed water is important in understanding what is occurring at depth. Two possibilities for the transport of water toward the surface are diffusion and hydrothermal fracturing (Davies, 1999). Transport rates with diffusion would be slow and the viscosity would have a minimal impact on flow rates. With fracturing, flow rates could be much higher and would be controlled by the viscosity of the water. It is thought that water may move much too quick for diffusion to be the type of transport. Transport of water from the subducted crust to the surface may be as little as 100 years (Turner, 2001). Fracturing could allow for higher rates of flow, but the viscosity of the fluid is important. A viscosity high enough to support the high flow rates would not discredit the fracture hypothesis. A viscosity too small would make the fracture hypothesis improbable. No viscosity experiments have been conducted under the temperature and pressure conditions present at 100 km depth (5 GPa and 1300 K).

The viscosity will be measured using the hydrothermal diamond cell (HDAC). Prior to using the HDAC to measure the viscosity at high pressure and temperatures, an analogous experiment must be conducted. This analog simulates the main experiment and proves that any results are valid.

## Method

The analogous experiment was conducted by duplicating the experiment's geometry and measuring the viscosity of water under conditions in which the viscosity is well known. The apparatus to be used in the high pressure and temperature experiment will be the Hydrothermal Diamond Anvil Cell (HDAC) (Bassett et al, 1993). High pressure is obtained squeezing a sample between the approximately 0.5 mm tips of two diamonds. This geometry was duplicated by using two glass slides clamped together.

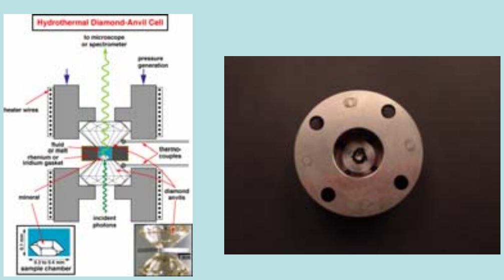


**Figure 2:** *Schematic diagram of the HDAC[1] (left) and photo of the HDAC with diamond in the center (right).*

**Figure 3:** *Profile view (left) of the analogous apparatus and overhead view (right). Rhenium gasket is circled in the second photo. Dimensions of the slide are 46 mm x 26 mm x 2 mm* and diameter of the gasket hole is 500 μm.

Both the HDAC and analog contain a 500 μm rhenium gasket under pressure. Within the central gap in the gasket, 3 μm polysteyrene particles are suspended in water and are observed for Brownian motions. Brownian motions are small, random movements that particles make with no preferred direction. A digital camera was used to record these motions. Video tracking software was then used to track the point throughout the video.

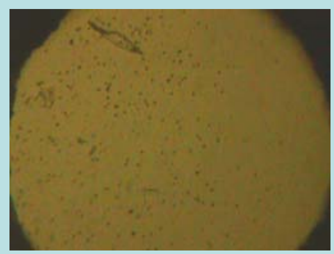

**Figure 4:** *Suspended particles in the 500 μm rhenium gasket.*

Using those data, the displacements of the particle per second were calculated and averaged for the entire 25 second video. The viscosity was then calculated using mean square displacement.

$$< r^2 >= \left( \frac{4kT}{6\pi\eta a} \right) t$$

k = 1.38 x $10^{-23}$ J/K
T = 298 K
a = 1.5 x $10^{-6}$ m
r = displacement (m)
t = time step (s)
η = viscosity (1 x $10^{-3}$ Pa·s at $10^5$ Pa and 298 K)

**Figure 5:** *Equation for mean square displacement; where k is the Boltzman's constant, T is the temperature and a is the particle radius.*

The particle motions needed to monitored for any preferential directions. Any preferential motion (such as linear motion) indicates non-random motion, due to particles in proximity to each other or a leak in the apparatus. These particles can not be used in the viscosity calculations.

## Results and Current Progress

Video analysis is still ongoing, but early indications are that the n valid. Initial analyses indicate a viscosity at standard temperature and pressure $^5$ Pa) to be close to previously established numbers of 1x$10^{-3}$ Pa·s (Audétat et al. iscosity obtained through analysis is 0.5x$10^{-3}$ Pa·s. A viscosity within an order considered suitable for the experiment.

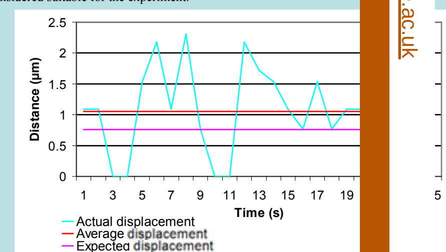


**Figure 6:** Graph showing the actual particle displacements, the avera nt and the calculated expected displacement.

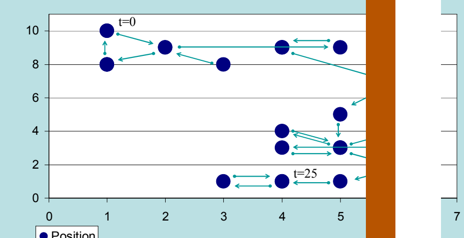


**Figure 7:** Graph indicating the relative random particle motions. Th on is at t=0 and final position is at t=25. Arrows indicate particle path.

More particles need analyzed in order to determine if the result is acc l datasets have been made, though only one has been completely analyzed ets were rejected due to minimal movement. Since the camera could view the en e gasket, it was determined that particles that hardly moved in relation to obably interacting with the surface of the glass slides.

Only when many particles are analyzed can statistics be done on the be determined if the method is truly valid. Future analyses also need to inc al magnification in order to reduce error. The data above did not use any a magnification. More points will be analyzed before the results can be co lusive, but the initial results are promising.

## References

1. Image from http://www.gfz-potsdam.de

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